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Thermal benefits of clumping aggregations in captive Blue-tongued Lizards

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Abstract
Captive Blotched Blue-tongued Lizards *Tiliqua nigrolutea* and Eastern Blue-tongued Lizards *T. scincoides* formed clumping aggregations that persisted for up to 3 hours after the sunlight had receded from their enclosure. The temperature within the aggregations was up to 12°C above ambient air temperature. Clumping aggregations occurred in all seasons except winter when lizards were inactive, with the largest aggregations occurring in spring and autumn. There was a strong association between the monthly frequency of aggregations and the maximum monthly aggregation size. (*The Victorian Naturalist* **139**(3), 2022, 64–69)

Keywords: aggregations, lizards, clump, temperature, captive, frequency

Introduction

Aggregations of lizards and snakes discovered in the field are typically encountered beneath ground debris rather than in the open and are usually discovered during periods of the year when the species concerned is inactive, i.e. these are over-wintering aggregations (e.g. Hoser 1980). There are, however, some exceptions, where aggregations of basking lizards and snakes occur during the day, often on top of, or at least in direct body contact with, one another. I call these 'clumping' aggregations. For example, many species of the genus *Egernia* live communally and are often seen basking together in direct body contact (e.g. Greer 1997); aggregations of gravid female snakes that bask in direct body contact with each other are also known to occur (Shine 1991). The common occurrence of clumping aggregations in captive reptiles, wherein individuals of one or several species lie on top of each other basking, are typically an artefact of limited enclosure space and/or the spatial concentration of resources, such as basking sites; nonetheless this behaviour would seem to benefit the individuals involved. Studies of these aggregations might shed some light on the significance of clumping aggregations observed in other species in the field.

In this work, clumping aggregations in a group of captive adult Blotched Blue-tongued Lizards *Tiliqua nigrolutea* and Eastern Blue-tongued Lizards *T. scincoides* are described; measurement of the temperature of the clumps, and their frequency of occurrence over a period of one year are presented.

Methods

A group of between 8 and 12 captive adult *T. nigrolutea* and 4 *T. scincoides* were kept together in an outdoor enclosure under semi-natural conditions north of Melbourne. All lizards were long-term captives and most had been maintained in the same enclosure for at least 5 years. Most were females, since unrelated males are extremely aggressive towards each other (G Turner, pers. obs. 1988–1997), but up to 4 related adult male *T. nigrolutea* (a father and his 3 male off-spring) were part of the group along with an adult male *T. scincoides*. The enclosure was constructed from a galvanised iron above-ground swimming pool surround, 76.2 cm in height. It was not a regular geometric shape: the west side abutted a north-south aligned fence and the east side a concrete path so that the eastern end was wider than the western end. Morning sunlight illuminated a narrow strip of the enclosure along the western side while late in the afternoon the sun illuminated just the south-eastern corner at the wide end; it was here that clumping aggregations occurred. A dual thermometer, comprising a small unit with an in-built thermometer and a temperature probe attached to the unit by a 3 m cord, was used to determine the ambient air temperature and clump temperature respectively. The clump temperature was determined by placing the probe in the 'centre' of the clump, in direct contact with lizards, thus measuring the body surface temperature of 2 or more lizards in the centre of the clump. On occasions the lizards'

movements resulted in the probe being dislodged from the clump, causing recordings to be discontinued. The ambient air temperature was recorded 20 cm above the ground approximately 0.5 m away from aggregations in the enclosure. A period of 15 minutes was allowed between the initial placement of the temperature probe and the commencement of readings to allow the unit to equilibrate. Both temperatures were recorded at regular intervals (usually every half-hour) as was the number of lizards in the aggregation, from the initial formation of the clump through to its complete break-up. The frequency of clumping, as measured by the number of days in each month that aggregations were observed, along with the maximum aggregation size, was also recorded. While aggregations of lizards were observed over several years, the data presented on monthly aggregation frequencies below is limited to just a single year (1992), when the data gathered was most complete and a group of 12 lizards was in the enclosure. For a small number of days (< 5) in some months, no clump size data was recorded. The chi-squared statistic (χ^2) was used to compare monthly aggregation frequencies with the equal monthly frequency distribution. Monthly maximum and minimum temperature data for the region was accessed from the Bureau of Meteorology website (BoM 2021) at the nearest recording station (LaTrobe University, Bundoora). The strength of association between variables was determined using Spearman's rho ρ (a non-parametric correlation coefficient) and was 2-tailed in all instances.

Observations and results

Small aggregations were initially formed in the mid-to-late afternoon as the sunlit portion of the enclosure gradually shrank to a corner where lizards gathered to bask. These aggregations coalesced to form a single clump as lizards began to move and position themselves so that they were in direct body contact with other lizards and typically consisted of multiple females and males of both species (Fig. 1). Initially, lizards would often position themselves on top of the clump, enabling them to gain access to the last sunlit portion of the enclosure, and then, once the sunlight had receded, attempted to bury themselves within the clump. The

posture of individual lizards within the clump consistently reflected their attempts to maximise body contact with neighbouring individuals. Their heads and tails were often tucked around to align with the contours of abutting individuals (Fig. 1). The clumps persisted for up to 3 hours after the enclosure was in complete shade and were up to 4 (but more usually 2 or 3) lizards deep. Typically, there was jostling for position, with lizards attempting to secure positions beneath others in the clump and they used their snouts to nudge and manoeuvre themselves beneath and between individuals. No overtly aggressive tactics were ever observed. Gravid females were often the last to leave a clump regardless of their position within it. They would regularly form clumping aggregations themselves (usually just 3 or 4 individuals) even during the summer months. Clumping aggregations typically dispersed with the outermost individuals leaving first, exposing individuals deeper within the clump. Once one or 2 lizards had left, clumps tended to break-up rapidly and, usually, most individuals had departed within 30 minutes. Clumping aggregations did not occur in the early morning, which was probably because of the enclosure's position and shape, since a broad section of it received morning sunlight. Lizards were observed to bask individually in morning sun, exposing their flattened dorsal surfaces, sometimes in direct contact with others but never clumped.

The changes in temperature and clump size for a single afternoon/early evening (2 November 1992) is given in Fig. 2 and is typical of the patterns recorded on other days. Figure 2a shows a plot of the clump temperature and ambient temperature versus time, demonstrating the rates of cooling of both to be similar and essentially linear with the clump temperature consistently 10 °C higher than ambient for approximately 2.5 hours. Figure 2b shows the corresponding change in the number of lizards in the clump during this time, showing a stable clump of 8 to 9 lizards being maintained for a period of 2 hours. The maximum difference recorded between the core clump and ambient temperature for all clumping aggregations was 12 °C. Overall, clump temperatures varied between 27 and 38 °C (n ≈ 180) with
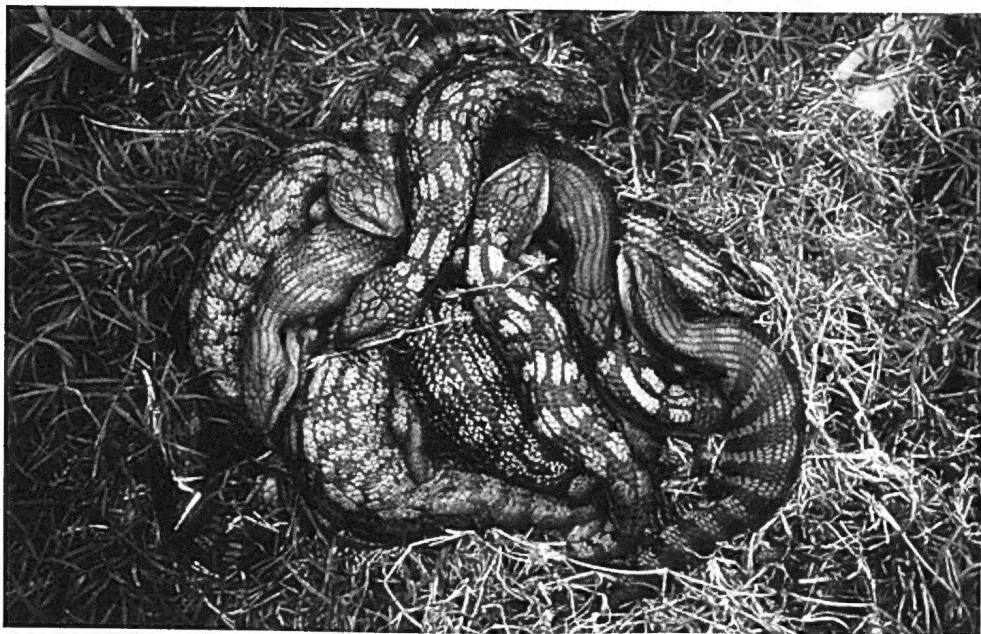
Fig. 1. Clumping aggregation of 12 captive adult Blotched Blue-tongued Lizards *Tiliqua nigrolutea* and Eastern Blue-tongued Lizards *T. scincoides.*

most (87%) above 30 °C; temperatures below 30 °C occurred mainly after clumps had begun to disperse.

The monthly frequency of clumping aggregations in Blue-tongued lizards is presented in Table 1 for the year 1992. Clumping aggregations did not occur at all during the coolest months (June to August) when lizards were inactive. In May, only a few individuals emerged during the day. The highest frequency of aggregations occurred in October. The largest aggregation size (12) also occurred in this month and again in November. The high frequency of aggregations recorded in January was likely the result of unusually cool conditions that occurred in that month (the lowest mean maximum temperature for January on record for the region; BoM 2021). During very warm weather, clumps consisted of just a few individuals (usually gravid females) or were not formed at all. For example, on one particular day when the ambient (shade) temperature was 38 °C, lizards remained at the shaded basking site but were spread out (centimetres apart) and not in direct body contact.

The number of aggregations recorded in each month was positively correlated with the maximum monthly aggregation size and this association was strong ($\rho = 0.88$, n = 9, $P = 0.002$; the observed zero frequencies corresponding to the 3 months of inactivity were removed) indicating that the largest aggregations occurred during the months when aggregations were most frequent. Both the observed monthly frequency and maximum monthly aggregation size were not significantly different from equal monthly frequency/size ($\chi^2 = 11.59/6.56$, 8df, $P = 0.170/0.585$ respectively); also, there were significant associations between these variables and the mean maximum/minimum monthly temperature ($\rho < 0.13$, n = 9, $P > 0.75$ for all).

Discussion

The formation of clumping aggregations described in this work are, in part, the result of lizards being kept together in a confined space, since *T. nigrolutea* and *T. scincoides* are not known to be communal nor to form aggregations during any period of the year in the wild (except for temporary consorts of adult mating pairs; Greer 1989; Koenig et al. 2001). Although

Fig. 2 (a). Plot of ambient and clump temperature (°C) versus time (hours, pm Eastern Standard Time) for a single clumping aggregation of captive adult Blotched Blue-tongued Lizards *Tiliqua nigrolutea* and Eastern Blue-tongued Lizards *T. scincoides*. The enclosure was in complete shade by 5 pm. Data collected on 2 November 1992.
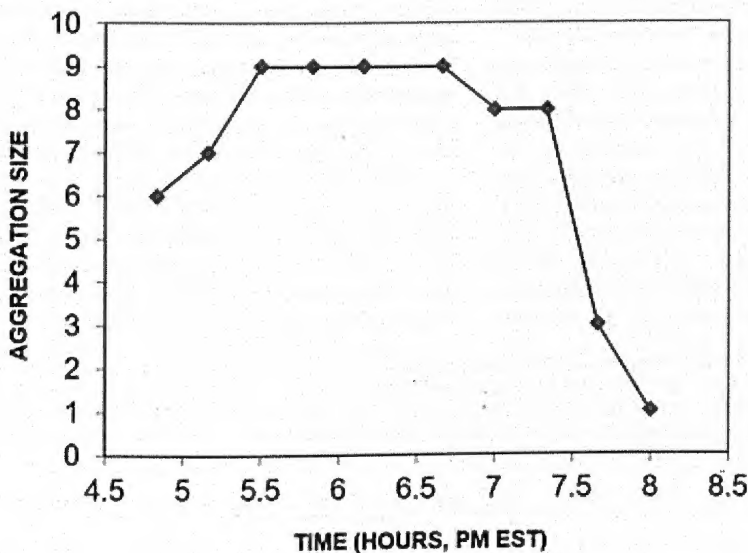

Fig. 2 (b). Plot of aggregation size versus time (hours, pm Eastern Standard Time) for the same clumping aggregation of Blotched Blue-tongued Lizards *Tiliqua nigrolutea* and Eastern Blue-tongued Lizards *T. scincoides*.

the captive environment makes clumping aggregations possible, it would seem that the desire of individual lizards to remain warm (i.e. maintain a stable, elevated body temperature) ultimately results in clump formation. This is supported by the smaller maximum clump sizes during the summer months, when warmer conditions generally prevailed, compared with spring and autumn, when aggregations were largest (Table 1). It is also supported by the individual lizards' behaviour in seeking positions within the clump where temperatures were higher as opposed to the periphery of the clump where they were most exposed to cooler air. The results indicate that being part of a clumping aggregation enabled lizards to maintained body temperatures well above ambient for 2 to 3 hours after the sunlight had receded. This, in turn, would likely aid food digestion and other metabolic and reproductive processes (i.e. embryonic development).

The mean preferred body temperature of adult *T. scincoides* varies from 31.9 to 32.6 °C recorded in both field and laboratory studies (Bartholomew et al. 1965, Koenig et al. 2001, Christian et al. 2003), while for *T. nigrolutea* it was found to be higher with a mean of 34.8 °C and a range of 31.9 to 37.7 °C (Rawlinson 1974). Clump temperatures were mostly between 30 to 38 °C, consistent with the preferred body temperature ranges. A field study (Koenig et al. 2001) of *T. scincoides* inhabiting suburban Sydney found that lizards achieved body temperatures between 30 to 35 °C by midday and maintained these until late in the evening. The authors attributed the high body temperatures after sunset to the Blue-tongues' 'high thermal inertia' and suggested that the high body temperature may be due to the selection of warm nocturnal retreats and heat-conserving postures. Heat-conserving postures were frequently exhibited by captive Blue-tongues in clumping aggregations (see above). The same study also found that gravid female *T. scincoides* maintained a more consistent body temperature by spending more time basking. The observations above of gravid females often being the last individuals to leave clumping aggregations, and also regularly forming aggregations in summer, appear to be behaviours aimed at achieving the same ends: a consistent, elevated body temperature.

Field observations and laboratory studies of clumping aggregations involving Australian squamates are few. A decrease in the rate of cooling of individuals in aggregations was demonstrated in neonate Tiger Snakes *Notechis scutatus* in the laboratory and it was also shown that the larger the aggregation, the lower the rate of cooling (Aubret and Shine 2009). Neonate *N. scutatus* have been recorded forming aggregations beneath cover in the field (Aubret and Shine 2009). Data from laboratory experiments on neonatal Central Bearded Dragons *Pogona vitticeps* suggested that aggregations occurred through mutual attraction to the heat source rather than for social reasons, and found that the mean body temperatures of lizards in aggregations were no different from those of solitary lizards; however, aggregation size was limited to just 3 individuals (Khan et al. 2010). Observations of Australian lizards forming clumping aggregations in the field exist for the Southern Snow Skink *Niveoscincus microlepidotus* and Tasmanian Tree Skink *N. pretiosus*, both of which form clumping aggregations of 3–6 individuals in the open in sunny, sheltered, cool situations (S Wilson, pers. comm. 29 January 2002; also S Wilson in Cawood 1997).

Table 1. Monthly data for the frequency of clumping aggregations in a group of 12 captive adult Blotched Blue-tongued Lizards *Tiliqua nigrolutea* and Eastern Blue-tongued Lizards *T. scincoides* in 1992. Between the months of May to August (inclusive) there was little or no activity. The last 2 rows are long term monthly mean maximum and minimum temperatures (°C) for La Trobe University, Bundoora. * = Lowest mean maximum temperature record for January (only 2 days > 30°C; BoM).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No. of aggregations	16	11	13	15	5	0	0	0	7	18	15	12
Max. aggregation size	10	6	8	11	6	0	0	0	5	12	12	9
Mean max. temp.	21.6*	24.3	24.4	20.8	16.3	13.3	13.1	13.2	13.9	18.8	19.8	23.9
Mean min. temp.	12.2	12.8	14.3	9.8	7.9	6.0	6.2	5.0	6.4	9.3	10.0	13.8

These skinks are confined to Tasmania and are considerably smaller in size than Blue-tongued Lizards (SVL 70 mm vs 300 mm; Wilson and Swan 2010). Smaller body size may, in part, explain why they form clumping aggregations as, being small, they lose heat to, and gain heat from, their surroundings more quickly by virtue of their greater surface area to volume ratio; forming a clump would effectively decrease this ratio (Heatwole and Taylor 1987; see Khan et al. 2010). In the field and under semi-natural conditions in captivity, the much larger Cunningham's Skink *Egernia cunninghami* (SVL 200 mm, Wilson and Swan 2010) has been regularly observed to form clumping aggregations when conditions were suitable for basking, often comprising mixed size classes (neonates through to adults; G Turner, pers. obs. 1990–2005). Because this species lives communally and, adults at least, occupy the same refuge for extended periods of time (e.g. Greer (1989), there is naturally the opportunity for clumping aggregations to occur. By contrast, Blue-tongued Lizards being neither communal nor sedentary in habit, would rarely have the opportunity to form clumping aggregations in the wild. Blue-tongues' large body size would mean that they lose heat more slowly to their surroundings and, therefore, the selection of suitably warm nocturnal retreats in the wild may help to maintain elevated body temperatures into the evening, similar to those achieved by clumping aggregations in captivity.

Acknowledgements

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Burnaia helicochorda, a predator of staurozoans in Victorian waters

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Abstract
The sea slug *Burnaia helicochorda* is reported to prey on several species of Stauromedusae. It is also reported to refuse hydroid medusae and anemones. *Burnaia helicochorda* possesses very large sensory rhinophores which we speculate assists the slug in finding its food. (*The Victorian Naturalist* 139(3), 2022, 70–74)

Keywords: Staurozoa, Stauromedusae, *Burnaia,* Nudibranchia, predation

Introduction
The aeolid nudibranch (sea slug) *Burnaia helicochorda* (Miller 1988) is an active sea slug, its slender body bearing many clusters of cerata along each side, and large densely lamellate rhinophores (head tentacles) so increasing the sensory surface area as to suggest perception of the slightest food scent at considerable distance. It is often found crawling about on seagrass and brown algae in lower intertidal rock pools. It had long been assumed that, because of its pectinate radular teeth, its prey was the common small anemone *Cricophorus nutrix* (Stuckey, 1909) living attached to the seagrass and brown algae (Burn 2015). Like *B. helicochorda*, this anemone also occurs in New Zealand (Grange 2010). It may be that *B. helicochorda* does eat *C. nutrix*, but in more than 40 years of observations, particularly by RB, we have never seen this happen. AF's failure to entice one to eat the other in aquarium or petri dish strongly suggests that *C. nutrix* is not on the preferred food list. Subsequent observations showed that the preferred prey are actually stalked jellyfish.

Stalked jellyfish, otherwise known as stauromedusans, are little upside-down marine jellyfish attached to the substrate by a pedal disk on a peduncle or stalk. They are presently classified as Class Staurozoa within the Phylum Cnidaria. They are little known in Victorian waters; 2 references (McInnes 1989; Falconer 2013) virtually covering the field. Since one of us (AF personal data; Zagal et al. 2011) has taken an interest in assessing what species might occur in our lower intertidal and shallow subtidal waters, 5 species have been recognised. At least 2 of these are new species and it is anticipated that ongoing studies will provide names for undescribed species and identifications for others.

Observations
Five separate observations of *B. helicochorda* feeding upon and eating specimens, or living in close proximity to stauromedusans, are detailed as follows:

1. A large specimen of *Calvadosia tasmaniensis* (Zagal et al. 2011), approximately 30 mm calyx diameter, was collected by AF from brown algae growing in a large intertidal rock pool at Shoreham Beach, Westernport Bay, Victoria on 13 September 2014. Microscopic examination of this specimen revealed a 10 mm long *B. helicochorda* buried between the gonads towards the centre of the calyx. Both nudibranch and stauromedusan were much the same colour, the white cnidosacs (nematocyst receptacles) in the tips of the cerata replicating the white dots scattered over the surface of the gonads. AF experienced difficulty dislodging *B. helicochorda* from its position between the gonads. LA photographed the two together (Fig. 1), and video recorded *B. helicochorda* as it fed. In these video segments, *B. helicochorda* can be seen with its mouth parts applied hard to the gonad, then as it moves to one side, a large tear is visible in the gonad wall with contents starting to weep out. The tear increases in size after each bite, its edges ragged as though the flesh has been torn away, not smooth as if cut with a sharp blade. (Fig. 2).

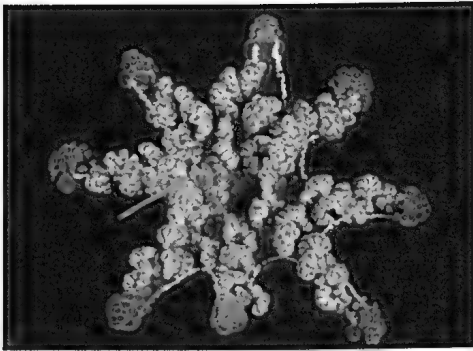2. A 6 mm diameter specimen of *C. tasmaniensis* and a 15 mm long specimen of *B. helico-*

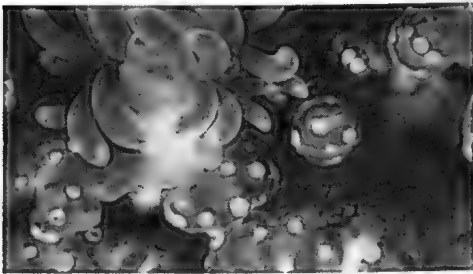**Fig. 1.** *Burnaia helicochorda* hiding in *Calvadosia tasmaniensis*, Shoreham Beach, 13 September 2014.

Fig. 2. *Burnaia helicochorda* feeding on gonads of *Calvadosia tasmaniensis*. Stills from video. Shoreham Beach, 13 September 2014.

Fig. 3. Three images of approach and attack on *Calvadosia tasmaniensis* by *Burnaia helicochorda*. Stills from video. Shoreham Beach, 13 September 2014.

chorda, both collected by AF from the same brown algae at the same locality, 13 September 2014, were placed together in a shallow tank for photographic documentation of what occurred when the specimens encountered each other (Fig. 3). Upon sensing the presence of *C. tasmaniensis* from about 10 mm distance, the *B. helicochorda* attacked aggressively by plunging its head directly into the open calyx, and commenced to feed upon the gonads. The oral tentacles of *B. helicochorda* moved about violently and indiscriminately, the rhinophores twitched rapidly and moved to a much lesser degree than the oral tentacles, and the anterior groups of cerata straightened and contorted following no pattern. These reactions may have been in response to stinging by nematocysts by the stauromedusan. Transparency of the head parts of *B. helicochorda* allowed the pharynx to be seen moving forward to the mouth opening, then moving back. Eventually, after several approaches over 3–4 minutes, the entire stauromedusan was consumed, and the *B. helicochorda* moved away. The whole process was video recorded by LA.

3. At Mozzie Flat, near Port Moorowie, Yorke Peninsula, South Australia, on 17 April 2014, RB observed specimens of *B. helicochorda* crawling across an open area of rock from one pool to the next in extremely shallow water (< 10 mm) as the incoming tide rose. AF observed that the stauromedusan *Haliclystus* sp. nov. was also present on seagrass and brown algae at this locality though none was searched for in the pools containing *B. helicochorda*.

4. At Kitty Miller Bay, Phillip Island, Victoria, 13 February 2008, AF found a large specimen of *B. helicochorda* (Fig. 4) located less than 30 cm away from a large specimen of *C. tasmaniensis* in a bed of the seagrass *Amphibolis antarctica*. The *C. tasmaniensis* had very patchy gonads and was missing 2 arms, which was noted as being unusual, since stauromedusans are not normally seen with this kind of damage (Fig. 5).

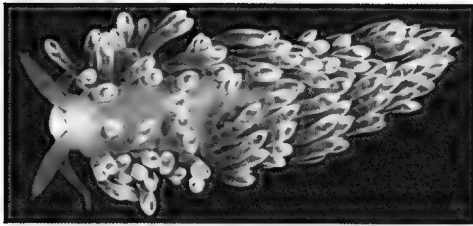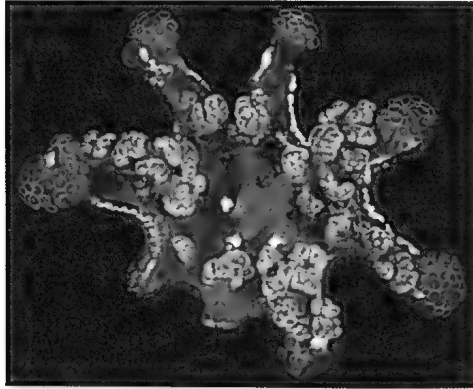**Fig. 4.** *Burnaia helicochorda.* Kitty Miller Bay, 13 February 2008.

Fig. 5. *Calvadosia tasmaniensis* showing damage sustained, with 2 arms missing. Kitty Miller Bay, 13 February 2008.

5. Following preparation of an early draft of this paper AF experimented with feeding *B. helicochorda* various food items to confirm our findings above. Specimens were collected at Shoreham Beach on 6 August 2016: *C. tasmaniensis* (3 specimens), *Criophorous nutrix* (2 specimens) and several specimens of the hydroid medusa *Gonionemus agilis* Watson & Govindarajan, 2017. One 15 mm specimen of *B. helicochorda* was found. Prior to feeding tests, one ceras was removed from the *B. helicochorda* and the nematocysts in it were observed using a ProSciTech OXJS500T Biology research infinity microscope (Fig. 6). Aeolids often retain nematocysts (stinging cells) from their prey in their cerata for their own defence. Finding nematocysts present is clear evidence of predation on the species that has these specific nematocysts. The combination of types, sizes and frequency of nematocysts is called the 'cnidome' and is unique to each cnidarian species. A number of the nematocysts were

Fig. 6. Nematocysts found in ceras. Note orange pigment from the *Burnaia helicochorda*. Shoreham Beach, 6 August 2016.

spent but many more were available to fire and all nematocysts were either isorhizas or euryteles with no other nematocyst types present, consistent with the cnidome of *Calvadosia tasmaniensis*. The *B. helicochorda* was offered *G. agilis*, which it investigated but did not attempt to attack after apparently being stung. It was then offered a *Cricophorus nutrix* from which it retreated rapidly after being stung. Then, when offered *C. tasmaniensis*, it promptly attacked and continued to attack despite being stung.

Discussion
These observations lead us to state confidently that the aeolid nudibranch *B. helicochorda* preys upon and eats stauromedusans.

Other nudibranchs (sea slugs) are also reported to feed on stauromedusans (Davenport 1998; Mills and Hirano 2007); however, no further details are provided in those reports. John Davenport, Yayoi Hirano and Claudia Mills have been kind enough to expand on their published remarks about predation as follows:
• The slug *Facelina bostoniensis* (Couthouy, 1838) feeds mainly on tubularians, and also stauromedusans and polyps of *Aurelia*. (John Davenport pers. comm. 2022);
• The slug *Pteraeolidia* cf. *semperi* has been observed to 'bite' *Haliclystus inabai* (Kishinouye, 1893) when kept in the same container. (Yayoi Hirano pers. comm. 2022);

• *Haliclystus sanjuanensis* Hyman, 1940 is a very common stauromedusan; however, it is never observed with damage that would be expected from predation. A recent report includes a photograph of the slug *Hermissenda opalescens* (J. G. Cooper, 1863) inside the calyx of *Haliclystus sanjuanensis*. Claudia Mills (pers. comm. 2022).

Zagal (2008) reports deformities in *Haliclystus auricula* James-Clark, 1863 that appear to be the result of predation—missing arms and anchors were observed in a total of 112 specimens out of the 3790 specimens studied. Zagal did not identify a culprit.

Burnaia helicochorda was originally described from northern New Zealand, where it remains an uncommon species (Willan 2010). It is not uncommon in south-eastern Australia, ranging from north-central New South Wales to central South Australia, including Tasmania (Burn 2006; 2015). Its pectinate radular teeth are characteristic of the nudibranch family Aeolidiidae, but its slender body, closely lamellate rhinophores, and long slender cerata mitigate against happy assignment within this family.

The recent molecular study of 2 specimens of *B. helicochorda* from Victoria (Carmona et al. 2015a) indicates that it has a closer relationship to members of the aeolid family Facelinidae, despite the fact that only 2 other species assigned to that family have pectinate radular teeth. Earlier molecular studies by Carmona et al. (2015b) show that these 2 species from tropical seas, *Protoaeolidiella atra* Baba, 1955 and *Pleurolidia juliae* Burn, 1966, long regarded as 'primitive members of the Aeolidiidae' are 'now clearly situated in Facelinidae'. This last outcome was supported by the feeding habits of these 2 species since they feed on the hydroid *Solanderia* instead of sea anemones and other anthozoans that represent the characteristic prey of aeolids (Gosliner et al. 2008; Carmona et al. 2015a). In response to the latter's claim that 'we were unable to find information about the diet of *B. helicochorda*', we pen this contribution regarding our observations.

The prevalence of *B. helicochorda* and its wide distribution in south-eastern Australia and rare occurrence in northern New Zealand would suggest a wide distribution for the stauromedusans upon which it feeds, even if restricted to

Fig. 7. Close-up of rhinophore of *Burnaia helicochorda*. Cape Patterson, 12 March 2008.

species of the genus *Calvadosia*. It also suggests that stauromedusans are far more common than present records indicate.

All nudibranch sea slugs have a pair of tentacular organs, the rhinophores, projecting dorsally from the anterior part of the body. Rhinophores are chemoreceptors by which the animal can locate food, find mates, and avoid predators (Wyeth and Willows 2006). Rhinophoral ornamentation, whether it be papillae, annulae or lamellae, increases the surface area receptive to chemosensory stimuli within the water column. The rhinophores of *B. helicochorda* are extremely large for the size of the animal at all stages of growth, but particularly so in juvenile specimens. In adults of this species, each rhinophore has between 20 and 30 close but distinct lamellae (Fig. 7), thereby greatly increasing the surface receptive area and enhancing the chemoreceptive capabilities of the animal. This in turn allows the animal to scan a broader, rather than proximate, water column for food, mates and predators. *Burnaia helicochorda* is thus well equipped to search for an elusive food such as stauromedusans.

None of the other sea slugs reported to eat stauromedusans possesses such equipment nor preys exclusively on stauromedusans.

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Changes in the dates of nest site inspections by Australian Wood Ducks (2003–2016)

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Abstract

As phenological data are rare in Australia, a 14-year record (2003–2016) of first nest site inspection dates by Australian Wood Ducks *Chenonetta jubata* is reported. Simple linear regression showed that the date of nest site inspections became earlier over the 14 years. However, correlation analyses of seasonal climate variables (mean maximum and minimum temperatures and total rainfall) for these observations did not reveal any significant relationships. (*The Victorian Naturalist* 139(3), 2022, 75–78)

Keywords: Australian Wood Duck, *Chenonetta jubata*, nest site, phenology

Introduction

The observations of life-stage events—such as first flowers, harvest dates or the arrival of migratory birds—have become indicators of a changing climate and its effects over the last thirty years or so (Cramer et al. 2014; Intergovernmental Panel on Climate Change [IPCC] 2007; Schwartz 1990). These phenological records have a long history in the northern hemisphere. For example, the flowering of cherry trees has been recorded in Japan since at least the 9th century (Aono and Kazui 2008), and wine harvest dates in Italy, France, Germany and Switzerland since the 15th century (Le Roy Ladurie and Baulant 1980; Mariani et al. 2009). Phenological networks focusing on native plant and agricultural life stages, pests and diseases, and migrating birds were established in the mid-18th century in Europe and early 19th century in the United States (Koch 2010; Stoller 1956). Additionally, individual naturalists in the northern hemisphere have also recorded their phenological observations since at least the 1700s (see Sparks and Carey 1995; White 1789).

In Australia, recommendations for phenological observations to be recorded have existed for over 160 years (Anon 1936; Archer 1854; Commonwealth Meteorology 1907; Maiden 1909; Prince 1891; von Mueller 1887–1888). However, with some notable exceptions such as the Royal Society of Tasmania and the former Victorian Forests Commission (Chambers and Keatley 2010a; Keatley et al. 2013), the observations made by organisations have not survived (Keatley et al. 2013) or the calls for regular observations have apparently not been taken up. Like their northern hemisphere counterparts, individual naturalists in the southern hemisphere have also recorded their observations (e.g. Chambers and Keatley 2010b; Rumpff et al. 2010), but these data are rarely readily available. Therefore, determining the effects of a changing climate on biodiversity is more difficult in Australia than in the relatively data-rich northern hemisphere.

Even where records exist, they are often inadequate, containing large gaps, varying in location or coming from locations that are not precisely known. One approach to overcoming these challenges is to combine such data, including data from museum collections (Duursma et al. 2018; Hällfors et al. 2020; Pearson 2020; Schaber et al. 2010), in order to build an overall dataset that is more powerful and useful. Such a technique emphasises the value of ensuring that even small, discrete phenological datasets are published, so that they may be accessed and used by future researchers.

In this context, this contribution reports on the dates that a pair (or maybe several pairs over time) of Australian Wood Ducks (also referred to as Maned Duck, Maned Goose and Blue Duck) *Chenonetta jubata* (Frith 1982) investigated a chimney as a nesting site in Ballarat, a regional city in Victoria, from 2003 to 2016.

Methods and observations
Australian Wood Ducks are obligate hollow-nesters; pairs investigate suitable sites together, with the female constantly calling, most often in the morning (Frith 1982; Fullagar 2005). Although not noted by either Frith (1982) or Marchant and Higgins (1990), Australian Wood Ducks are known to occasionally use chimneys as their nesting sites (Birdlife Australia undated). The constant calling as a pair inspected a chimney as a nest site first drew my attention to their presence, although the chimney was never selected as a nesting site. Annual observations of the date of their first presence over 14 years provide a useful, discrete phenological dataset (Table 1).

Table 1. Annual dates of first nest site inspections of a chimney by Australian Wood Ducks, 2003–2016.

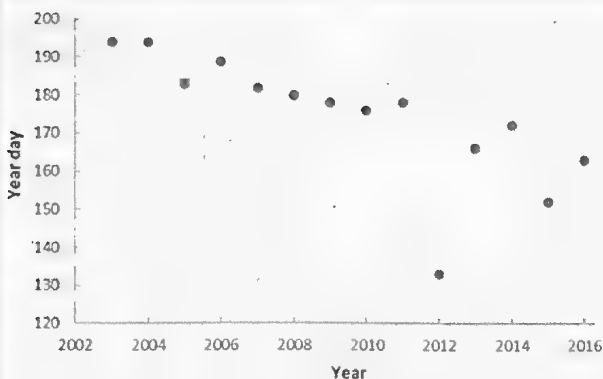| Date	Year	Year day
13 July	2003	194
12 July	2004	194
2 July	2005	183
8 July	2006	189
1 July	2007	182
28 June	2008	180
27 June	2009	178
25 June	2010	176
27 June	2011	178
12 May	2012	133
15 June	2013	166
21 June	2014	172
31 May	2015	152
12 June	2016	163

The dates of first nest site inspections each year were converted to year-days (Table 1) and examined by linear regression to determine whether there had been a change in nest site inspection dates. Change-point analysis (Taylor 2002, 2003) was also used to identify years in which a shift may have occurred in the inspection dates.

Climate has been shown to influence the arrival, departure and peak abundance of many Australian bird species (Chambers 2010; Chambers et al. 2013). For the Australian Wood Duck, summer minimum temperatures have been found to correlate with their peak abundance (Chambers 2010). Therefore, the relationship between first nest site inspection dates and seasonal climate variables (mean maximum and minimum temperatures, and total rainfall) were examined by correlation. Climate data were sourced from the Bureau of Meteorology (Ballarat Aerodrome; Station No: 089002), approximately 9.5 km from the observation site.

Results
Although this is a relatively short data set, the examination of the nest site inspection dates by linear regression analysis indicates that, over the 14 years, they became significantly earlier (3.0 days/year, P = 0.002) (Fig. 1). The result remains significant (2.6 days/year, P < 0.001) with the exclusion of the outlier date (year-day 133 in 2012).

The earliest inspection date, year-day 133, oc-

Fig. 1. Annual year-days of first potential nest site inspections of a chimney by Australian Wood Ducks, 2003–2016.
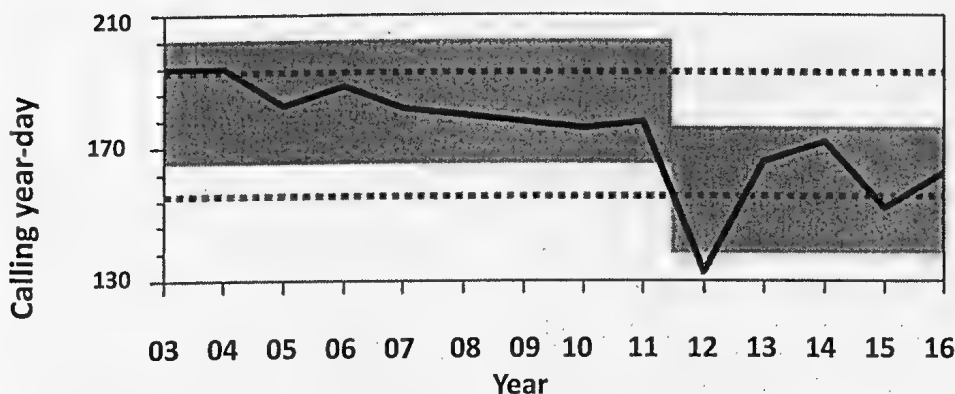
Fig. 2. Results of the change point analysis which identifies 2012 as the year the date of nest site inspections changed.

curs in 2012. Change-point analysis confirms 2012 as the change point year (Fig. 2). The average inspection date prior to 2012 is year-day 184 (2 July); after 2012, it is 157 (5 June) (P < 0.001). If the year 2012 is removed as an outlier, the analysis then identifies 2013 as the change point year. The average inspection date prior to 2013 remains year-day 184 (2 July) but after 2013 it is 6 days later, on year-day 163 (11 June) (P = 0.02).

Correlation analyses of seasonal climate variables (mean maximum and minimum temperatures and total rainfall) with the nest inspection dates do not reveal any significant relationships; but mean summer minimum temperatures show a moderate negative trend, albeit non-significant (r = -0.51, P = 0.063).

Discussion

This small study indicates that first nest inspection dates became earlier over a 14-year period. This may indicate earlier breeding—assuming that earlier nest inspection dates are correlated with egg laying. The consequences of this shift could be larger brood sizes (Kingsford 1989). However, other factors, such as food resources, also influence brood sizes (Kingsford 1989; Marchant et al. 2021).

The seasonal climate variables examined in this study were not shown to have a significant correlation with the observed first inspection dates. While there was a non-significant moderate negative correlation with mean summer minimum temperature, this was not significant

at the P = 0.05 level. This could be because other climate variables, such as El Niño–Southern Oscillation (ENSO) and differences such as those recorded in the Southern Oscillation Index, play a more important role in influencing Australian Wood Duck inspection behaviour. These variables have been found to affect the start of avian breeding (Duursma et al. 2018; Marchant et al. 2021). Additionally, any change in the start of avian breeding noted in this study could be reflective of the shortness of the data set (n = 14 years)—in general terms, when examining the relationship between climate and phenological variables, it is recommended that data series should span at least 15 years (Sparks and Menzel 2002; van de Pol et al. 2016).

Finally, the difficulty of compiling and accessing numerous discrete phenological datasets emphasises the need to centralise and archive such data. In an attempt to address the lack of readily available phenological records in Australia, an App and website (ClimateWatch https://www.climatewatch.org.au/) have been developed by EarthWatch Australia, the Bureau of Meteorology and the University of Melbourne, focusing on phenological events of approximately 180 species, including some found in marine environments.

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Notes on the butterflies of the Pilliga Forest in northern inland New South Wales, Australia

Introduction

Australia has a significant and interesting butterfly (Lepidoptera) fauna with a large proportion of endemic species. The greatest species richness is found in the Torresian province of the tropics and subtropics and the highest proportion of endemicity is found in the Bassian province in the south-east and south-west of the continent, while the butterfly fauna of the arid zone (Eyrean province) is relatively depauperate (Common and Waterhouse 1981; Orr and Kitching 2010). In New South Wales (NSW), butterfly species diversity is highest along the mesic east coast and rapidly declines west of the Great Dividing Range (Kitching et al. 1999; Braby 2000). The Pilliga Forest, in northern inland NSW, is one of the largest surviving temperate woodland remnants in inland eastern Australia's agriculture-dominated western slopes bioregions. It is an important biodiversity hotspot for a range of fauna groups including reptiles, frogs, birds and invertebrates such as decapod crustaceans, pupillid land snails and butterflies, largely due to its location in a biogeographic overlap zone between Torresian, Bassian and Eyrean faunal assemblages (Date et al. 2002; Murphy 2011, 2016, 2019; Murphy and Shea 2013; Murphy et al. 2021). The butterfly fauna of the Pilliga Forest was described by Murphy (2019), recording 63 species from 5 families and documenting information on broad spatial and temporal patterns of local species diversity. The present paper complements Murphy (2019), providing additional information on some of the butterfly species recorded.

Study Area and Methods

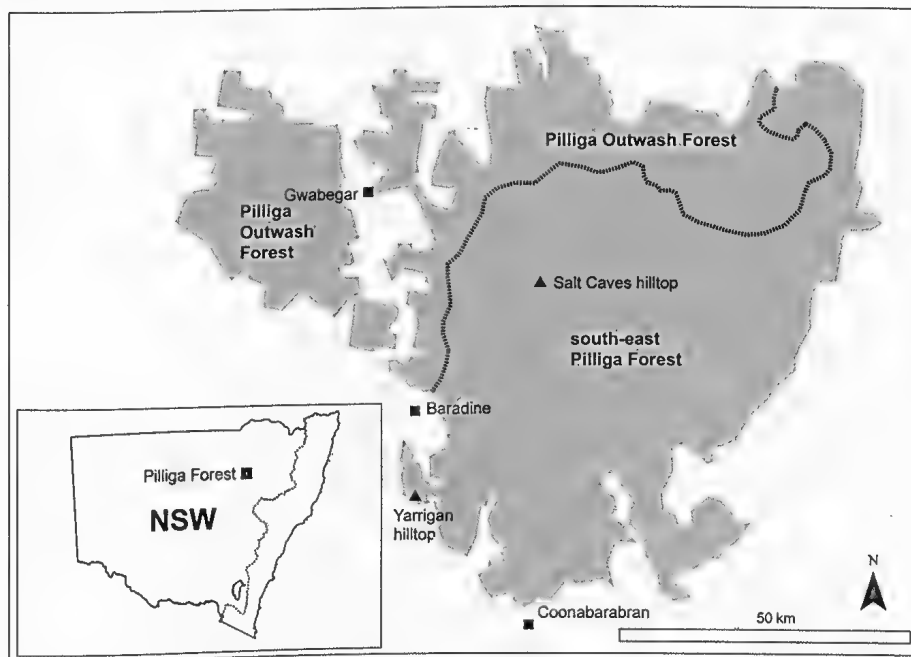The 450 000 ha Pilliga Forest (30°25'–31°15'S, 148°40'–149°50'E) (Fig.1) is located in

Fig. 1. Pilliga Forest study area. The dotted line on the inset map marks the Great Dividing Range.

Gamilaraay Aboriginal Country between Coonabarabran and Narrabri in the Brigalow Belt South bioregion, on the outer western slopes of the Great Dividing Range. The forest comprises a mosaic of woodland and open forest communities with various *Eucalyptus, Callitris, Angophora, Corymbia, Acacia* and *Allocasuarina* species and occupies 2 landform units: undulating sandstone country in the east and south-east and the apex of an alluvial outwash fan in the north and west. The adjacent Coonabarabran and Baradine townships and Gwabegar village were included in the study area.

Records of adult butterflies in the study area were collated from field surveys undertaken at least monthly over the period 2011–2017, complemented by opportunistic observations in 2006–2010 and records obtained from secondary sources (Murphy 2019). The survey period included both *La Niña* and *El Niño* conditions. The full range of vegetation communities present throughout the Pilliga Forest was investigated, with repeat surveys at pre-selected sites augmented by opportunistic sampling. All recorded species were assigned to one of 5 local status categories based on overall frequency of detection: rare (1–3 records), uncommon (4–30 records), common (31–100), very common (101–200) and abundant (> 200).

Two hilltop sites were each visited on over 20 occasions between the months of September and May to investigate hilltopping activity by butterflies: Yarrigan tower hilltop (Yarrigan National Park) (31°4.55'S, 149°4.38'E) in the south-east Pilliga Forest; and Salt Caves hilltop (Timmallallie National Park) (30°44.76'S, 149°17.43'E) in the central Pilliga Forest (Fig. 1). For each species recorded at hilltop sites, frequency of detection at the site was calculated (expressed as a percentage of the total visits to the site) and the activity period noted.

Results and Discussion

A dataset of 4164 butterfly records (including 12 records from secondary sources) in the Pilliga Forest was collated, comprising 63 species from 5 families. A list of species with information on frequency of detection in the study area is provided in Table 1, together with the national status of each species (from Braby (2016). Fifteen hilltopping species were recorded at

the Yarrigan hilltop site and 9 at the Salt Caves hilltop site (Table 2). The hilltopping butterfly community at the Salt Caves site included one species not found at the Yarrigan site and also a higher frequency of occurrence of some others (Table 2).

The butterfly fauna of the Pilliga Forest comprises a mix of Torresian, Bassian and Eyrean species. Species with a northern (Torresian) distribution include Lemon Migrant, Large Grass-yellow, Scarlet Jezebel, Blue Tiger, Glasswing and Spotted Grass-blue (see Table 1 for scientific names). Southern (Bassian) species include Heath Ochre, Spotted Jezebel, Common Brown, Ringed Xenica, Yellow Admiral and Fringed Heath-blue. Species occurring widely through inland (Eyrean) areas of the continent include Chequered Swallowtail, Small Grass-yellow, Lesser Wanderer, Meadow Argus and Satin Azure. The majority of species have a national status of either 'common to very common and widespread' (26 species – 41%) or 'common to very common but localised to very localised' (30 species – 48%) (Braby 2016). Three species (Common Crow, Common Brown and Common Grass Blue) are in the 'superabundant and widespread' national category, of which one (Common Crow) was locally uncommon. Two species (Yellow Ochre and Golden Azure) are in the 'uncommon to rare and very local' categories (Braby 2016).

Some of the interesting butterflies found in the Pilliga Forest are illustrated. Information on general biology is from Braby (2000), Orr and Kitching (2010) and Braby (2016). The six most frequently recorded species in the Pilliga Forest were the Caper White (Fig. 2), Cabbage White (Fig. 3), Lesser Wanderer (Fig. 4), Meadow Argus (Fig. 5), Australian Painted Lady (Fig. 6) and Common Grass Blue (Fig. 7). All 6 are common and widespread at the national level (Braby 2016). The Cabbage White, accidentally introduced from Europe, where it is known as the Small White (Lewington 2004), was most commonly seen around the margins of the Pilliga Forest adjacent to farmland, while the remaining five were widespread throughout the forest. Mass migrations of Caper Whites were sometimes observed, with large numbers of butterflies all flying in the same direction.

Table 1. Butterfly species list for the Pilliga Forest. Local status in study area (based on frequency of detection): A = abundant, VC = very common, C = common, U = uncommon, R = rare. National status (from Braby (2016)): SA/W = superabundant and widespread, VC/W= very common and widespread, VC/L = very common but local, VC/VL = very common but very local, C/W = common and widespread, C/L = common but local, C/VL = common but very local, U/W = uncommon and widespread, U/VL = uncommon and very local, R/VL = rare and very local.

Family	Species	Local status	National status
Hesperiidae – Skippers	Heath Ochre *Trapezites phigalia*	U	C/L
	Montane Ochre *Trapezites phigalioides*	R	C/L
	Yellow Ochre *Trapezites luteus*	R	R/VL
	Orange Ochre *Trapezites eliena*	R	C/L
	Barred Skipper *Dispar compacta*	R	C/W
	Banded Grass-skipper *Toxidia parvula*	U	C/VL
	Dingy Grass-skipper *Toxidia peron*	R	C/W
	Varied Sedge-skipper *Hesperilla donnysa*	R	C/L
	White-banded Grass-dart *Taractrocera papyria*	R	U/W
	Narrow-brand Grass-dart *Ocybadistes flavovittatus*	R	C/W
	Green Grass-dart *Ocybadistes walkeri*	C	C/W
Papilionidae – Swallowtails	Orchard Swallowtail *Papilio aegeus*	VC	C/W
	Chequered Swallowtail *Papilio demoleus*	C	C/W
	Dainty Swallowtail *Papilio anactus*	C	C/W
Pieridae – Whites & Yellows	White Migrant *Catopsilia pyranthe*	C	VC/W
	Lemon Migrant *Catopsilia pomona*	R	VC/W
	Macleay's Grass-yellow *Eurema herla*	R	C/W
	Small Grass-yellow *Eurema smilax*	VC	C/W
	Large Grass-yellow *Eurema hecabe*	U	VC/W
	Cabbage White *Pieris rapae*	A	VC/W
	Striated Pearl-white *Elodina parthia*	U	C/W
	Narrow-winged Pearl-white *Elodina padusa*	U	C/W
	Caper White *Belenois java*	A	VC/W
	Yellow-spotted Jezebel *Delias nysa*	R	C/L
	Spotted Jezebel *Delias aganippe*	U	C/W
	Scarlet Jezebel *Delias argenthona*	C	C/L
	Black Jezebel *Delias nigrina*	R	C/L
Nymphalidae – Nymphs	Blue Tiger *Tirumala hamata*	R	VC/W
	Lesser Wanderer *Danaus petilia*	A	C/W
	Monarch *Danaus plexippus*	C	C/L
	Common Crow *Euploea corinna*	U	SA/W
	Glasswing *Acraea andromacha*	U	C/W
	Australian Painted Lady *Vanessa kershawi*	A	VC/W
	Yellow Admiral *Vanessa itea*	C	C/W
	Meadow Argus *Junonia villida*	A	C/W
	Varied Eggfly *Hypolimnas bolina*	U	C/W
	Tailed Emperor *Charaxes sempronius*	U	U/W
	Common Brown *Heteronympha merope*	VC	SA/W
	Ringed Xenica *Geitoneura acantha*	U	C/L
	Grey Ringlet *Hypocysta pseudirius*	C	C/VL
Lycaenidae – Blues	Chequered Copper *Lucia limbaria*	R	C/L
	Fiery Copper *Paralucia pyrodiscus*	U	C/VL
	Satin Azure *Ogyris amaryllis*	U	C/L
	Silky Azure *Ogyris oroetes*	R	C/L
	Broad-margined Azure *Ogyris olane*	R	C/L
	Golden Azure *Ogyris ianthis*	R	U/VL
	Southern Purple Azure *Ogyris genoveva*	R	C/VL
	Imperial Hairstreak *Jalmenus evagoras*	U	VC/L
	Amethyst Hairstreak *Jalmenus icilius*	R	VC/VL
	Varied Dusky-blue *Candalides hyacinthinus*	C	C/L

Table 1. cont

Family	Species	Local status	National status
Lycaenidae – Blues	Twin Dusky-blue *Candalides geminus*	R	C/L
	Yellow-spotted Blue *Candalides xanthospilos*	R	C/L
	Rayed Blue *Candalides heathi*	U	C/VL
	Two-spotted Line-blue *Nacaduba biocellata*	C	VC/W
	Fringed Heath-blue *Neolucia agricola*	U	C/L
	Cycad Blue *Theclinesthes onycha*	U	C/L
	Wattle Blue *Theclinesthes miskini*	C	C/L
	Saltbush Blue *Theclinesthes serpentatus*	VC	VC/L
	Long-tailed Pea-blue *Lampides boeticus*	C	C/W
	Plumbago Blue *Leptotes plinius*	R	C/L
	Orange-tipped Pea-blue *Everes lacturnus*	R	C/L
	Spotted Grass-blue *Zizeeria karsandra*	U	VC/L
	Common Grass-blue *Zizina otis*	A	SA/W

Table 2. Frequency of detection and activity period for butterfly species at 2 hilltopping sites in the Pilliga Forest (See Table 1 for scientific names).

	Yarrigan (28 visits)		Salt Caves (23 visits)	
	Freq. (%)	Activity period	Freq. (%)	Activity period
Hilltopping species				
Heath Ochre	7	September–November	-	-
Montane Ochre	4	October	-	-
Orange Ochre	4	October	-	-
Dingy Grass-skipper	11	February–March	-	-
Spotted Jezebel	21	October–May	26	October–February
Scarlet Jezebel	25	September–May	9	March–April
Australian Painted Lady	57	September–May	-	-
Tailed Emperor	43	October–March	9	October–April
Common Brown	21	February–April	4	December
Grey Ringlet	29	October–May	30	October–April
Varied Dusky-blue	39	October–March	78	October–March
Two-spotted Line-blue	7	November–February	-	-
Cycad Blue	-	-	4	March
Wattle Blue	32	October–March	48	October–May
Saltbush Blue	32	November–April	4	March
Long-tailed Pea-blue	46	October–May	-	-
Other species				
Banded Grass-skipper	4	-	-	-
Greenish Grass-dart	4	-	-	-
Orchard Swallowtail	43	-	4	-
Small Grass-yellow	11	-	4	-
Cabbage White	7	-	-	-
Striated Pearl-white	4	-	4	-
Narrow-winged Pearl-white	4	-	-	-
Caper White	39	-	9	-
Lesser Wanderer	39	-	9	-
Meadow Argus	25	-	-	-
Common Grass-blue	79	-	9	-

Australian Painted Lady and Meadow Argus were present throughout the year. Although usually seen at ground level, both species were attracted to grass-tree *Xanthorrhoea* spp. flower spikes. Lesser Wanderers were often seen feeding at flowers of the introduced Farmer's Friend *Bidens pilosa*. Congregations of hundreds of

Common Grass Blues were occasionally seen on the wet margins of ground tanks and remnant waterholes during hot, dry weather.

The number of skipper species (Hesperiidae) found in the Pilliga Forest is relatively high for a western slopes location (Murphy 2019). Two species are illustrated. The Green Grass-dart
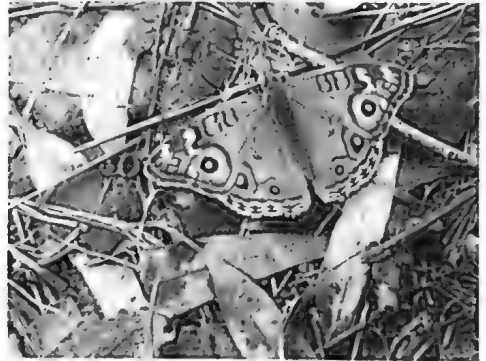

Fig. 2. Caper White *Belenois java.*

Fig. 5. Meadow Argus *Junonia villida.*

Fig. 3. Cabbage White *Pieris rapae.*

Fig. 6. Australian Painted Lady *Vanessa kershawi.*

Fig. 4. Lesser Wanderer *Danaus petilia.*

Fig. 7. Common Grass-blue *Zizina otis* congregated at water during hot weather.

(Fig. 8), widespread in eastern Australia and also found in northern Australia, was the most commonly recorded skipper, comprising three-quarters of all skipper records. It was recorded from early spring to late autumn and was typically found at ground level in areas with a grassy understorey, often near streams. It also visited gardens. The Montane Ochre (Fig. 9) is apparently rare in the Pilliga Forest. This species is found in eucalypt forest on and near the Great Dividing Range. Western Slopes records are generally from highland areas such as Coolah Tops, Mount Kaputar and the Warrumbungles (Daniels 1979; Atlas of Living Australia 2022). The single Pilliga Forest record was from the Yarrigan tower hilltop site (460 m elevation) in October. Flight was fast and low with frequent perching on the ground.
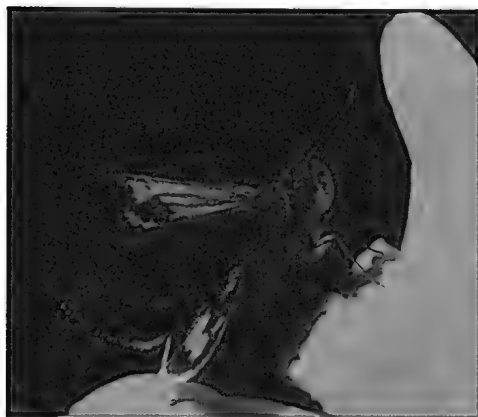
Three swallowtails (Papilionidae) were found in the Pilliga Forest. The Orchard Swallowtail (Fig. 10) was the most frequently recorded (very common), while the Chequered Swallowtail (Fig. 11) and Dainty Swallowtail (Fig. 12) were common. All 3 were generally seen
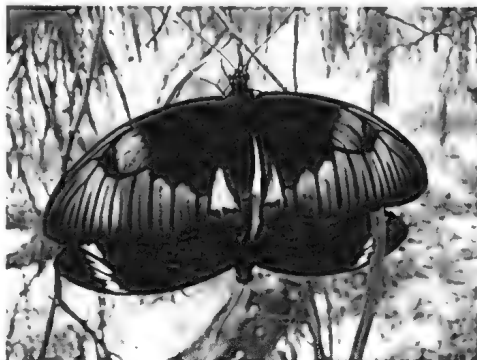

Fig. 10. Mating pair of Orchard Swallowtails *Papilio aegeus* on Wilga.

Fig. 8. Green Grass-dart *Ocybadistes walkeri.*

Fig. 11. Chequered Swallowtail *Papilio demoleus.*

Fig. 9. Montane Ochre *Trapezites phigalioides* (vouchered specimen).

Fig. 12. Dainty Swallowtail *Papilio anactus.*

from early spring to late autumn, although Chequered Swallowtail was occasionally seen in late winter. Orchard Swallowtails and Dainty Swallowtails were seen visiting citrus trees in gardens in addition to observations in the forest. The mating pair of Orchard Swallowtails pictured were on a Wilga *Geijera parviflora*, a known larval food plant. Chequered Swallowtails were often seen feeding at flowers of introduced *Verbena* spp.

Four jezebel species (Pieridae) have been recorded in the Pilliga Forest, of which 3 are illustrated. The Scarlet Jezebel (Fig. 13) was common while the Spotted Jezebel (Fig. 14) was uncommon. Both were often seen flying at canopy height at hilltopping sites. The Yellow-spotted Jezebel (Fig. 15) was recorded only once in the Pilliga Forest, when it was found in a Coonabarabran garden in Janu-

ary. This species favours rainforest habitats, ranging from coastal rainforest to dry inland vine thickets. Additional members of the Pieridae illustrated are the White Migrant (Fig. 16), Lemon Migrant (Fig. 17) and Large Grass-yellow (Fig. 18). The White Migrant was a common

Fig. 15. Yellow-spotted Jezebel *Delias nysa*.

Fig. 13. Scarlet Jezebel *Delias argenthona*.

Fig. 16. White Migrant *Catopsilia pyranthe*.

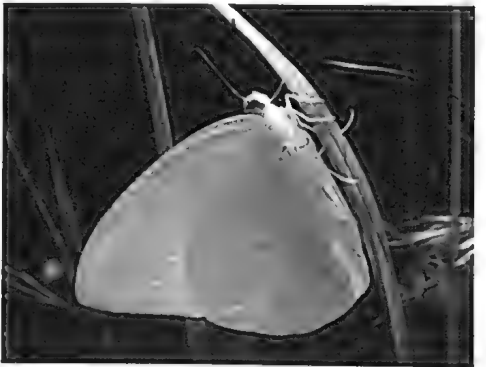**Fig. 14.** Spotted Jezebel *Delias aganippe*.

Fig. 17. Lemon Migrant *Catopsilia pomona*.

and widespread resident in the Pilliga Forest, seen from early spring to late autumn, while the Lemon Migrant was a rare visitor with records from the western Pilliga Outwash Forest in September and March. The Large Grass-yellow was an uncommon but regular visitor between late summer and early winter.

Additional Browns (Nymphalidae) ranged from common residents to species visiting only during wet years. The Common Crow (Fig. 19), Varied Eggfly (Fig. 20) and Grey Ringlet (Fig. 21) were regularly seen during *La Niña* years but were scarce or absent during *El Niño* conditions. The Common Brown (Fig. 22) and Ringed Xenica (Fig. 23) were both recorded between mid-spring and mid-autumn, but while the Common Brown was widespread and very common, the Ringed Xenica was uncommon and restricted to a few sheltered gullies in the south-east Pilliga Forest. The

Monarch (Fig. 24), a self-introduced species from North America, was common and recorded throughout the year. It was most often seen along major streams in the south-east Pilliga Forest, where larvae were found in July on the introduced Cottonbush *Gomphocarpus fruiti-*

Fig. 20. Varied Eggfly *Hypolimnas bolina.*

Fig. 18. Large Grass-yellow *Eurema hecabe.*

Fig. 21. Grey Ringlet *Hypocysta pseudirius.*

Fig. 19. Common Crow *Euploea corinna.*

Fig. 22. Common Brown *Heteronympha merope* (male).

cosus, a member of the milkweed family. The Tailed Emperor (Fig. 25) was uncommon in the Pilliga Forest between mid-spring and mid-autumn. This large, fast-flying butterfly was usually observed at hilltop sites, flying back and forth at canopy height and occasionally stopping to perch head-down high in the canopy.

The species diversity of Blues (Lycaenidae) recorded in the Pilliga Forest was also comparatively high for the western slopes (Murphy 2019). Additional species illustrated are the Two-spotted Line-blue (Fig. 26), Wattle Blue (Fig. 27), Long-tailed Pea-blue (Fig. 28) and Imperial Hairstreak (Fig. 29). Two-spotted

Fig. 23. Ringed Xenica *Geitoneura acantha*.

Fig. 26. Two-spotted Line-blue *Nacaduba biocellata*.

Fig. 24. Monarch *Danaus plexippus*.

Fig. 27. Wattle Blue *Theclinesthes miskini*.

Fig. 25. Tailed Emperor *Polyura sempronius* perched head down in canopy on a hilltop.

Fig. 28. Long-tailed Pea-blue *Lampides boeticus*.

Line-blues and Wattle Blues were seen throughout the year including winter, while the Long-tailed Pea-blue was seen between early spring and late autumn. Two-spotted Line-blues were often seen fluttering in numbers around flowering shrubs including Gargaloo *Parsonia eucalyptophylla*, wattles *Acacia* spp. and Wilga in summer. Wattle Blue and Long-tailed Pea-blue were common and widespread, and both were often seen hilltopping. Ant-tended pupae of the Imperial Hairstreak (Fig. 30) were found on wattle shrubs in December and adults were seen between early summer and mid-autumn.

Fig. 29. Imperial Hairstreak *Jalmenus evagoras*.

Conclusion

The Pilliga Forest is significant as one of the largest surviving woodland remnants on the NSW western slopes and has one of the richest recorded butterfly faunaa of any location on the NSW western slopes and adjacent plains. The diverse butterfly fauna reinforces the high biodiversity value of the Pilliga Forest, which is an important area for invertebrate conservation (Murphy 2011, 2019, 2020; Murphy and Shea 2013). The observations documented here contribute to our understanding of the area's butterfly fauna.

Fig. 30. Imperial Hairstreak *Jalmenus evagoras* (pupa with attendant ants).

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Diversity of flowers visited by the Noisy Miner *Manorina melanocephala* in a small suburban residential area

The Noisy Miner *Manorina melanocephala* is a widespread honeyeater in eastern Australia, renowned for its ability to adapt to human-modified landscapes (Adams 2018; Griffin and Diquelou 2015; Callaghan et al. 2019). This bird is a common sight in urban and suburban Sydney, where it is a threat to smaller foliage-dwelling birds (Caterall 2010; Parsons et al. 2006). The species is listed as a Key Threatening Process in New South Wales. It forages on whatever is edible, from nectar, fruits, and insects, to bread, meat, and butter (Higgins et al. 2006), as well as lerps and honeydew (Adams 2018; the authors' pers. obs). Nectar from flowers is an important energy-source for honeyeaters (Franklin and Noske 2000; Nicolson and Fleming 2014) and all the more so for the Noisy Miner, which vigorously defends flower patches within its feeding areas (Caterall 2010).

We report here on the diversity of flower species visited by the Noisy Miner in a small suburban residential area in Sydney, studied from February 2021 to May 2022. We walked along 22 street sections that functioned as transects (33°49'45"S, 151°04'41"E to 33°49'59"S, 151°04'29"E, and 33°49'46"S, 151°04'41"E to 33°49'41"S, 151°04'26"E), which bordered 3 residential complexes with landscaping plants and easily visible gardens. We walked daily on the street section (362 m) with more plants and weekly on the street section (125 m) with fewer plants. We surveyed blooming plants of several types and colours to examine the Noisy Miner's use of this nectar source. Flower-visiting birds were observed with the unaided eye and documented with a 70–300 mm lens digital camera, from a distance of 3 to 6 m (Fig. 1). During the observational sessions, we used the '*ad libitum*' and 'sequence' samplings (Altmann 1974), both adequate to record temporary or unpredictable events. We examined the behaviour of Noisy Miners on the flowers of each visited plant, and noted the outcome of the visits (e.g. fruit formation).

We recorded 15 flower species visited by the Noisy Miner over the one-year period at our

Fig. 1. A Noisy Miner takes nectar from a flower of the New Zealand Flax *Phormium tenax*, a typical bird-pollinated species. Note the reproductive parts of the flower touching the bird's forehead.

study sites. Most of the visited flowers were red, and the plants' habits varied from herbs to trees (Table 1).

Typical bird-pollinated flowers predominated among those visited by the Noisy Miner, such as the red flowers of the New Zealand Flax *Phormium tenax* and the Gymea Lily *Doryanthes excelsa*. This latter plant has a large inflorescence and sturdy flowers adequate to receive visits by medium-sized to large honeyeaters (Fig. 2). On the other hand, we also recorded the Noisy Miner taking nectar from somewhat unexpected flowers, such as the typically insect-

Fig. 2. A Noisy Miner takes nectar from a flower of the Gymea Lily *Doryanthes excelsa*, another typical bird-pollinated species. Note the reproductive parts of the flowers touching the bird's underparts.

Table 1. Plants visited by the Noisy Miner Manorina melanocephala in a small suburban residential area in Sydney. E= exotic planted, N= native planted, W= exotic weed.

Families	Species	Colours	Habits
Amaryllidaceae	*Agapanthus praecox*[E]	blue or white	herb
Apocynaceae	*Araujia sericifera*[W]	white or pink	vine
Asphodelaceae	*Phormium tenax*[E]	red	herb
Doryanthaceae	*Doryanthes excelsa*[N]	red	herb
	Doryanthes palmeri[N]	red	herb
Musaceae	*Strelitzia nicolai*[E]	white	herb
	Strelitzia reginae[E]	orange	herb
Myrtaceae	*Callistemon viminalis*[N]	red	shrub
	Corymbia ficifolia[N]	red	tree
	Eucalyptus robusta[N]	white	tree
	Metrosideros collina[E]	red	shrub
	Xanthostemon chrysanthus[N]	yellow	tree
Proteaceae	*Banksia ericifolia*[N]	orange	shrub
	Grevillea bipinnatifida[N]	pink	shrub
Rosaceae	*Camellia chinensis*[E]	red	shrub

pollinated flowers of the Blue Lily *Agapanthus praecox* and the Moth Plant *Araujia sericifera* (Fig. 3).

Whereas visits to typical bird-pollinated flowers were recorded daily while in bloom, visits to typical insect-pollinated flowers (3 species)

Fig. 3. A Noisy Miner takes nectar from a flower of the Moth Plant *Araujia sericifera*, a typical insect-pollinated species. Note the bird's bill and forehead within the flower.

were recorded on only one occasion each, irrespective of their blooming period. Of the 15 flower species visited by the Noisy Miner, 14 produced fruits, and one (the Fuchsia Grevillea *Grevillea bipinnatifida*) yielded no fruits.

Flower-visiting behaviour by the Noisy Miner was solitary on most plants, except for the Swamp Mahogany *Eucalyptus robusta*, the Golden Penda *Xanthostemon chrysanthus*, and the Fuchsia Grevillea *Grevillea bipinnatifida*. On these 3 plant species, 2 to 5 individuals were recorded foraging at the same time. Chases could occur between the birds during visits to the same plant.

Besides visiting flowers, we observed Noisy Miner foraging for fruits and insects, both on vegetation and on the ground (Fig. 4).

All Meliphagidae (69 honeyeater and 2 chat species) visit flowers for nectar and some species are dependent on this food source (Ford et al. 1979; Nicolson and Fleming 2014; Adams 2018). This energy-rich food source is aggressively disputed by some honeyeater species, including the Noisy Miner (Ford and Paton, 1977; Caterall 2010).

Fig. 4. A Noisy Miner holds a planthopper (Hemiptera). Note orange pollen of recently visited flowers of the New Zealand Flax *Phormium tenax* on the bird's forehead.

In conclusion, even within a small suburban residential site the Noisy Miner retains its ecological functions as pollinator, disperser, and predator, delivering ecosystem services (*sensu* Sekercioglu 2006) by increasing gene flow among plants, dispersing seeds, and preying on herbivorous insects (Ford et al. 1979).

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Sixty-eight years ago

PROTECTIVE HABITS OF THE YELLOW-TUFTED HONEYEATER

By W. PERRY

Much has been said and written of the Noisy Miner, *Myzantha melanocephala*, sometimes known as the Soldier Bird. I have observed this bird and heard its alarm notes at a nest with young. When approached by human beings, and also at the presence of a pair of butcher-birds, much noise was made by the parents, and other Noisy Miners added their alarm notes also. Compared with the Yellow-tufted Honeyeater, I regard the Noisy Miner as an alarmist, the call might almost be regarded as hysterical. For action, I prefer the Yellow-tufted Honeyeater.

From *The Victorian Naturalist* **71**, p. 109, November 4, 1954

JRNL NHS